Phosphorous dynamics in soil and dust: a XANES application

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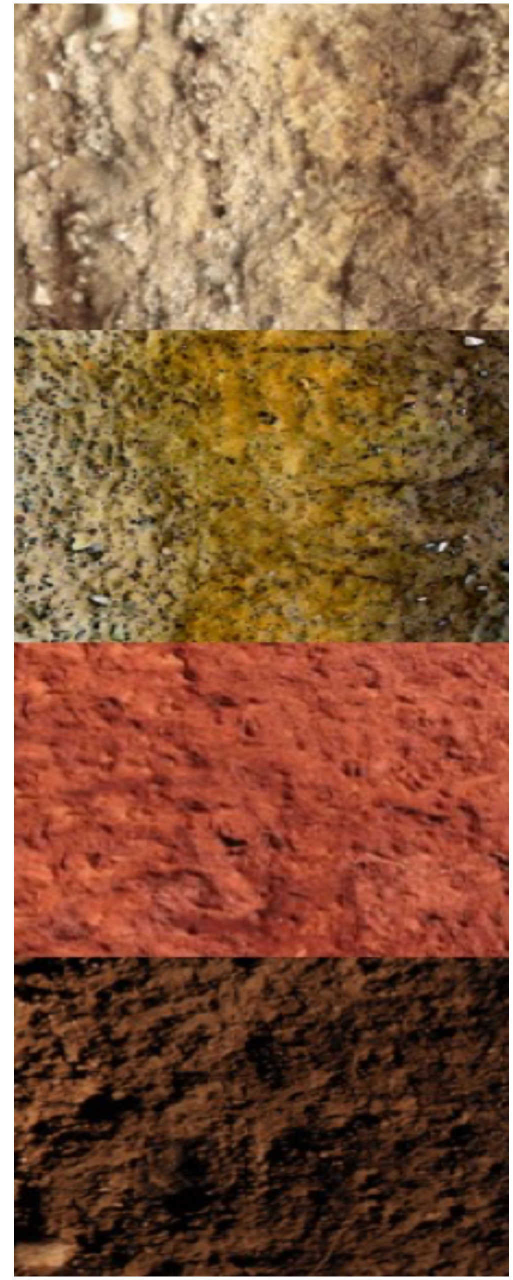

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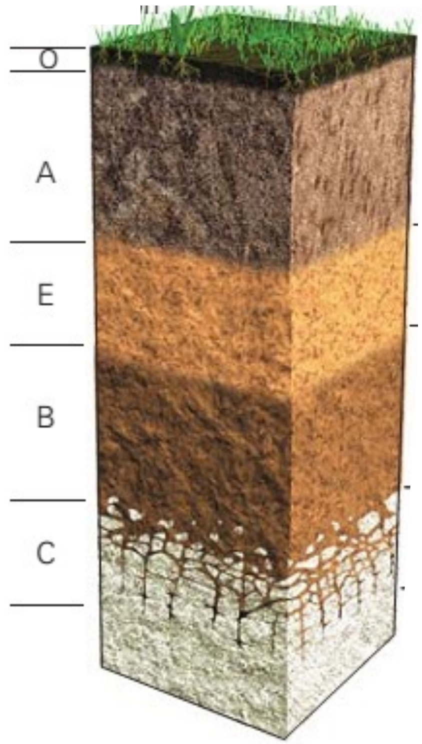

Responses

- JEDI in the academy
- Biogeochemical cycles of C (and PyC), N, P
- Vertical and lateral transport of soil and SOM , and terrestrial → aquatic)
- Nano-(bio)geochemistry
- Political ecology. Sustainability use of soil resource, Soil – society relations

Spatial scales: nano to catchment
Temporal scales: <minutes to >1000s of years

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Outline

- P speciation in soil
    - Effects of climate and soil weathering
- P in Dust
    - Composition and bioavailability
- Concluding thoughts

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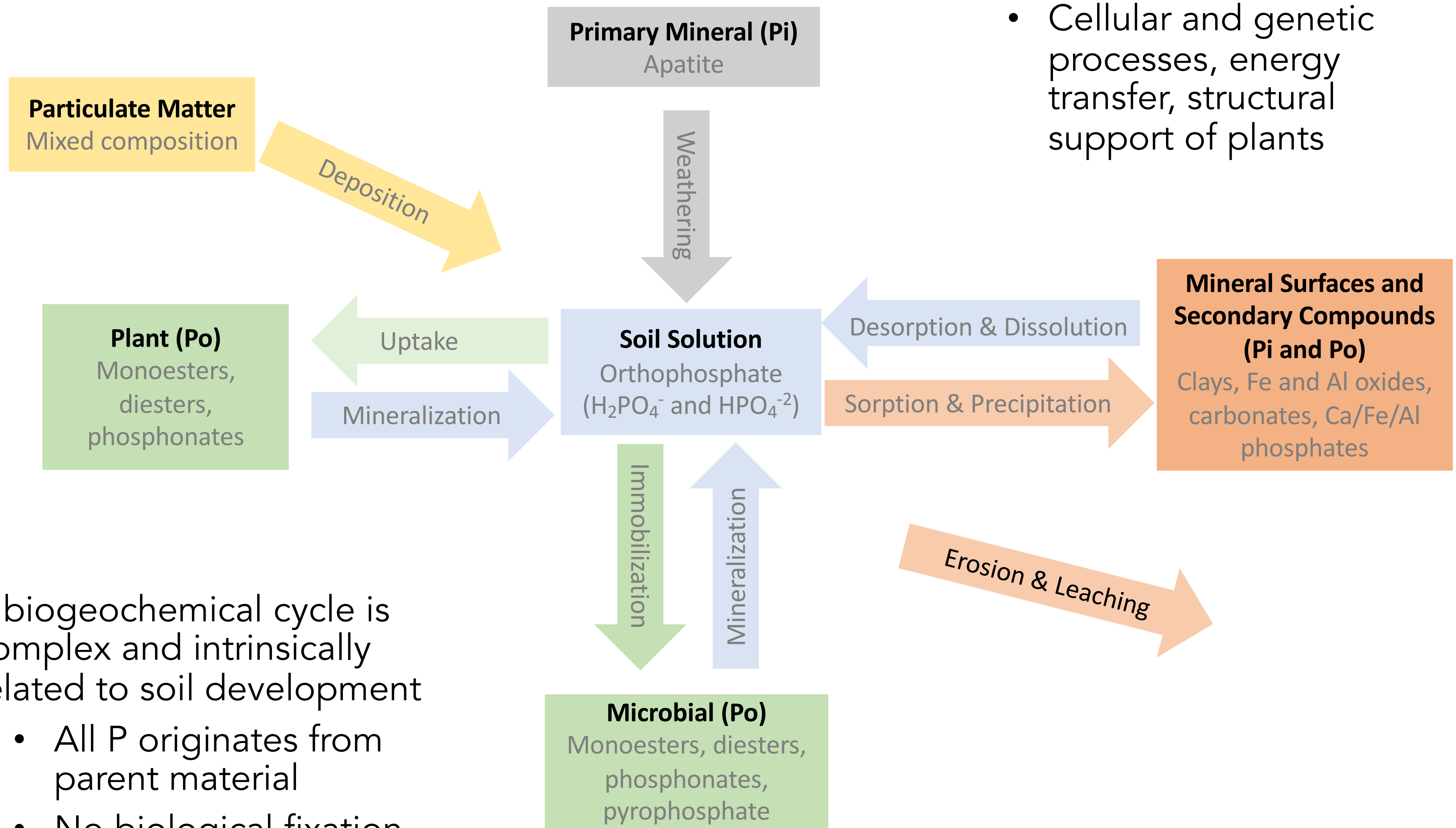
P Biogeochemistry

- P is an important macronutrient
  - Cellular and genetic processes, energy transfer, structural support of plants



- P biogeochemical cycle is complex and intrinsically related to soil development
  - All P originates from parent material
  - No biological fixation-> ultimately limiting nutrient

Barnes et al. (In Prep)

[Based on Kruse et al., 2015; Tiessen et al., 1984; Walbridge et al., 1991; Tiessen and Moir, 1993]

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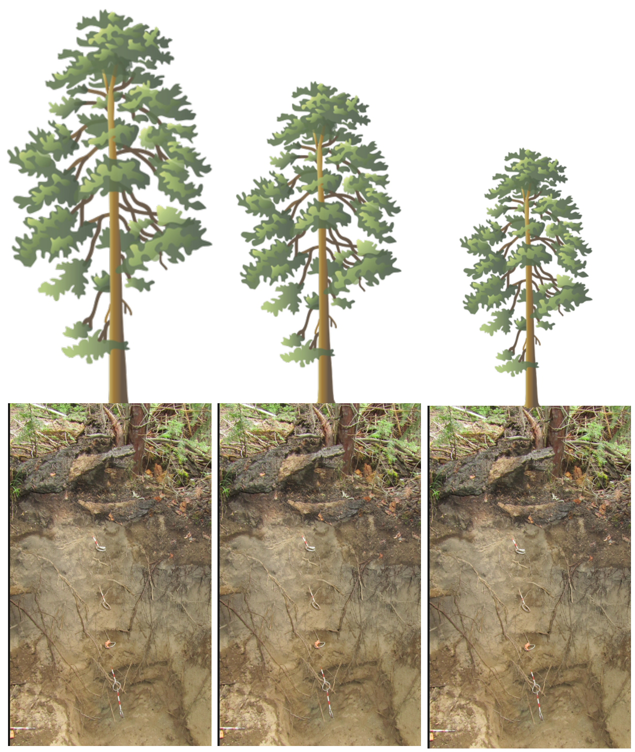
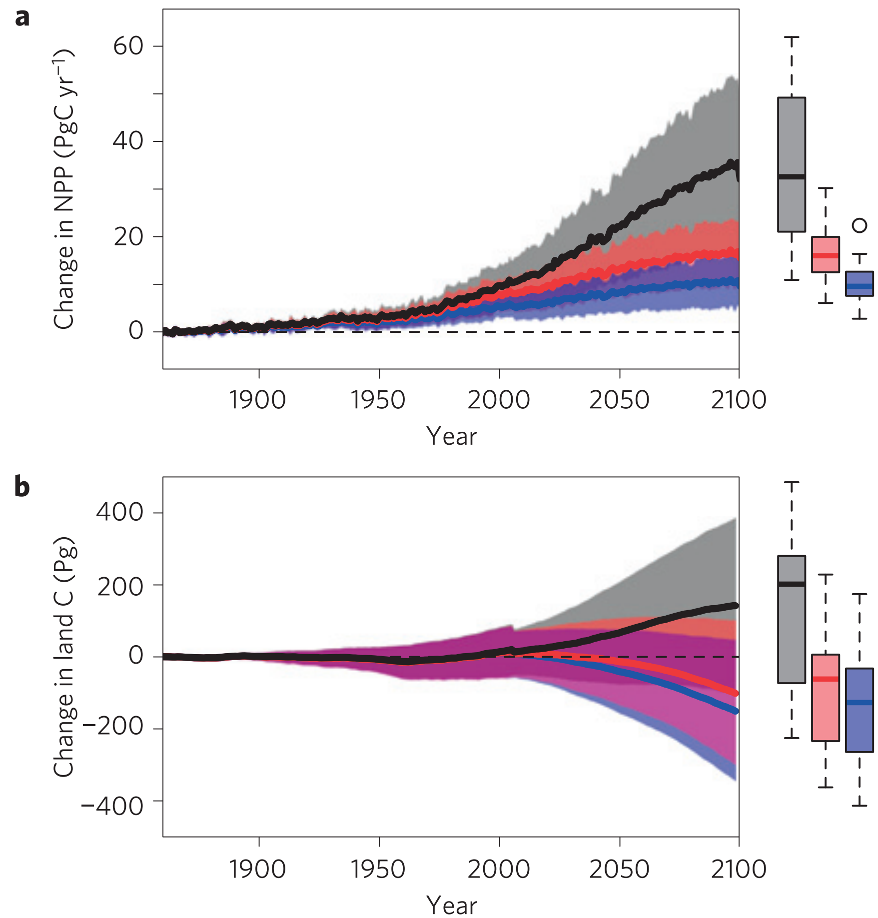
Global Nutrient Limitation

- Nitrogen and Phosphorus limit net primary productivity (photosynthesis) and terrestrial sequestration of atmospheric carbon dioxide.
  - global climate change concerns

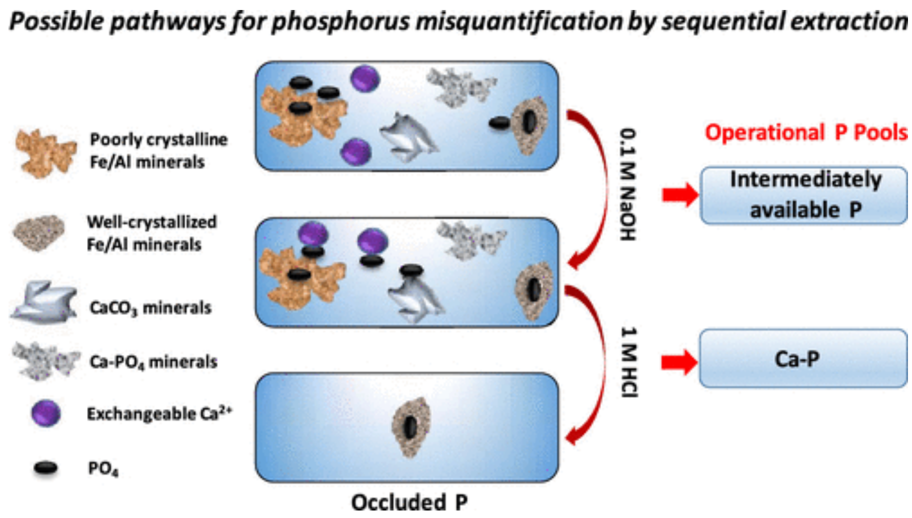


No nutrient limitation | N inputs | N+P inputs



Wieder et al. (2015) model projections of terrestrial C storage where the black line represents no nutrient limitation, red is N inputs, and blue is N+P inputs.

P XANES for soil, sediment, dust



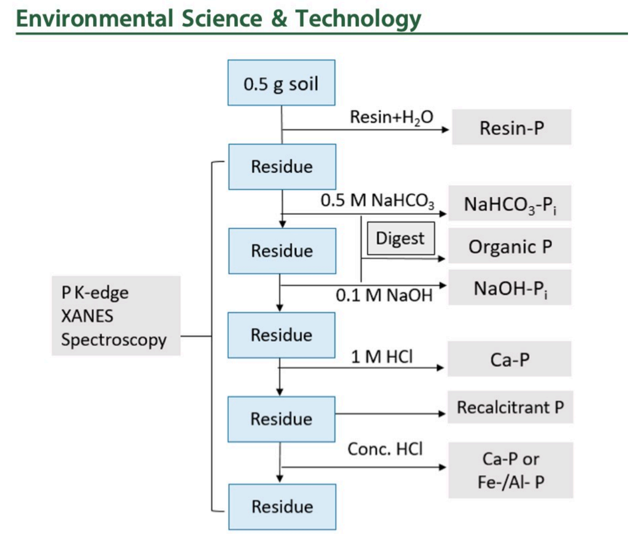
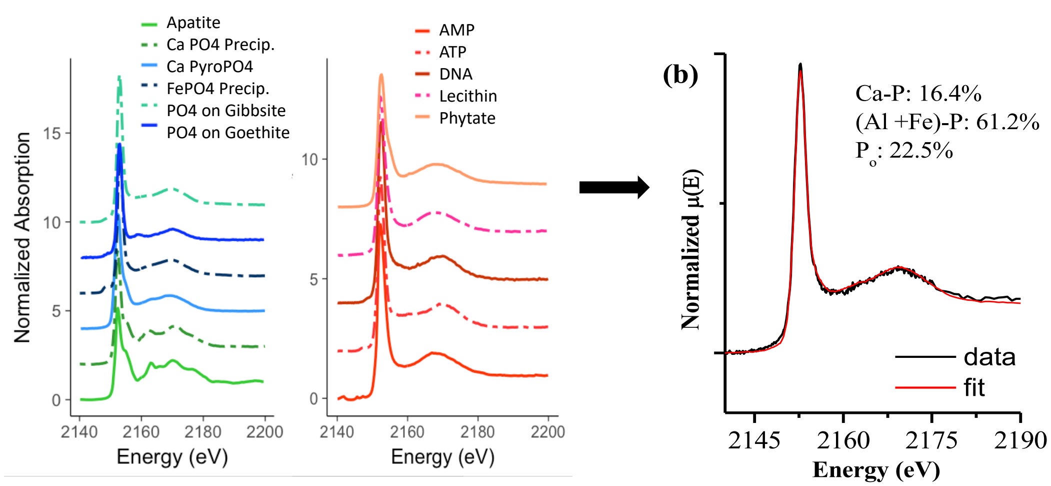


Figure 1. Flow chart for modified Hedley fractionations combined with phosphorus K-edge X-ray absorption near-edge structure (XANES) spectroscopic analysis.

Linear combination fitting analysis of P XANES spectra



Reference P XANES spectra

- Advantages:
  - Allows identification and quantification of different P pools: (Fe+Al)-P, Ca-P & organic P
  - In situ, non-destructive, & minimal sample pretreatment
- Work conducted at the Canadian Light Source and Stanford Linear Accelerator Center

Barnes et al. (In Prep); Gu et al. 2020 ES&T

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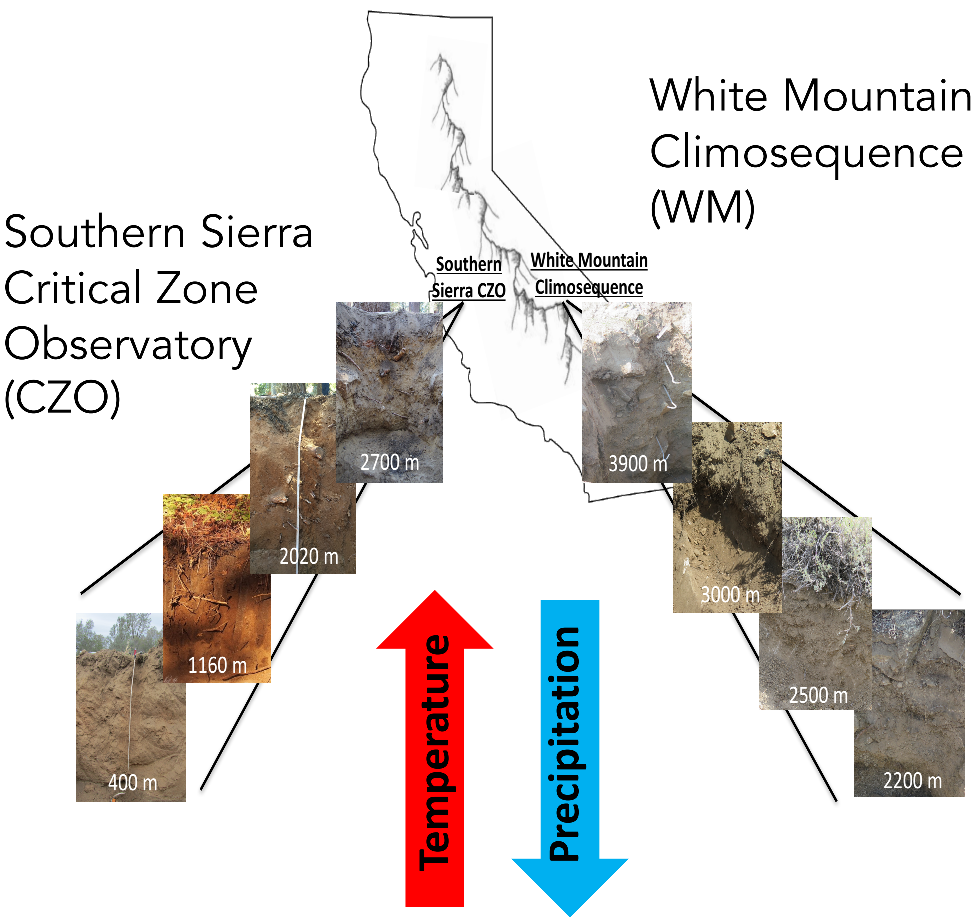
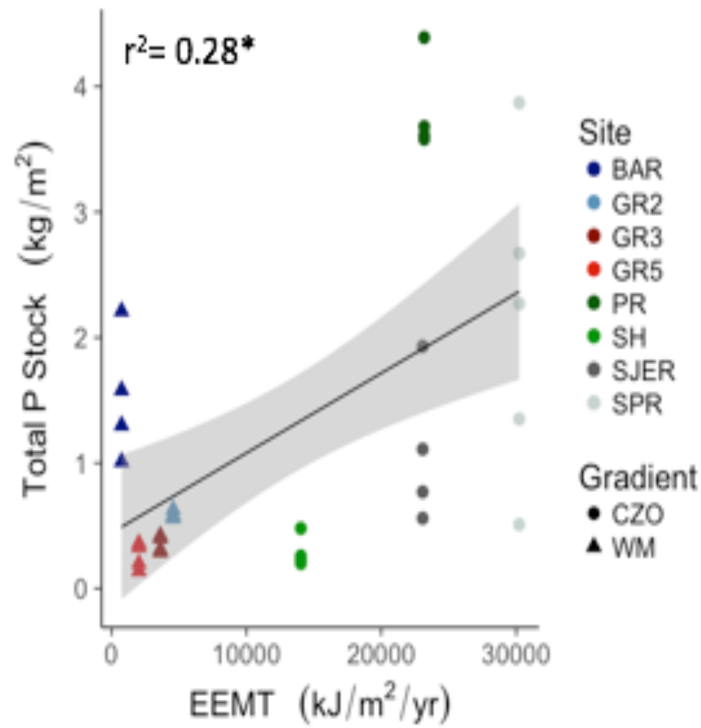
P speciation in soil

- Knowledge gap: Few observations on how P speciation changes along climatic gradients
  - Especially in areas with low P containing parent material and in Mediterranean and arid ecosystems





Barnes et al. (In Prep)

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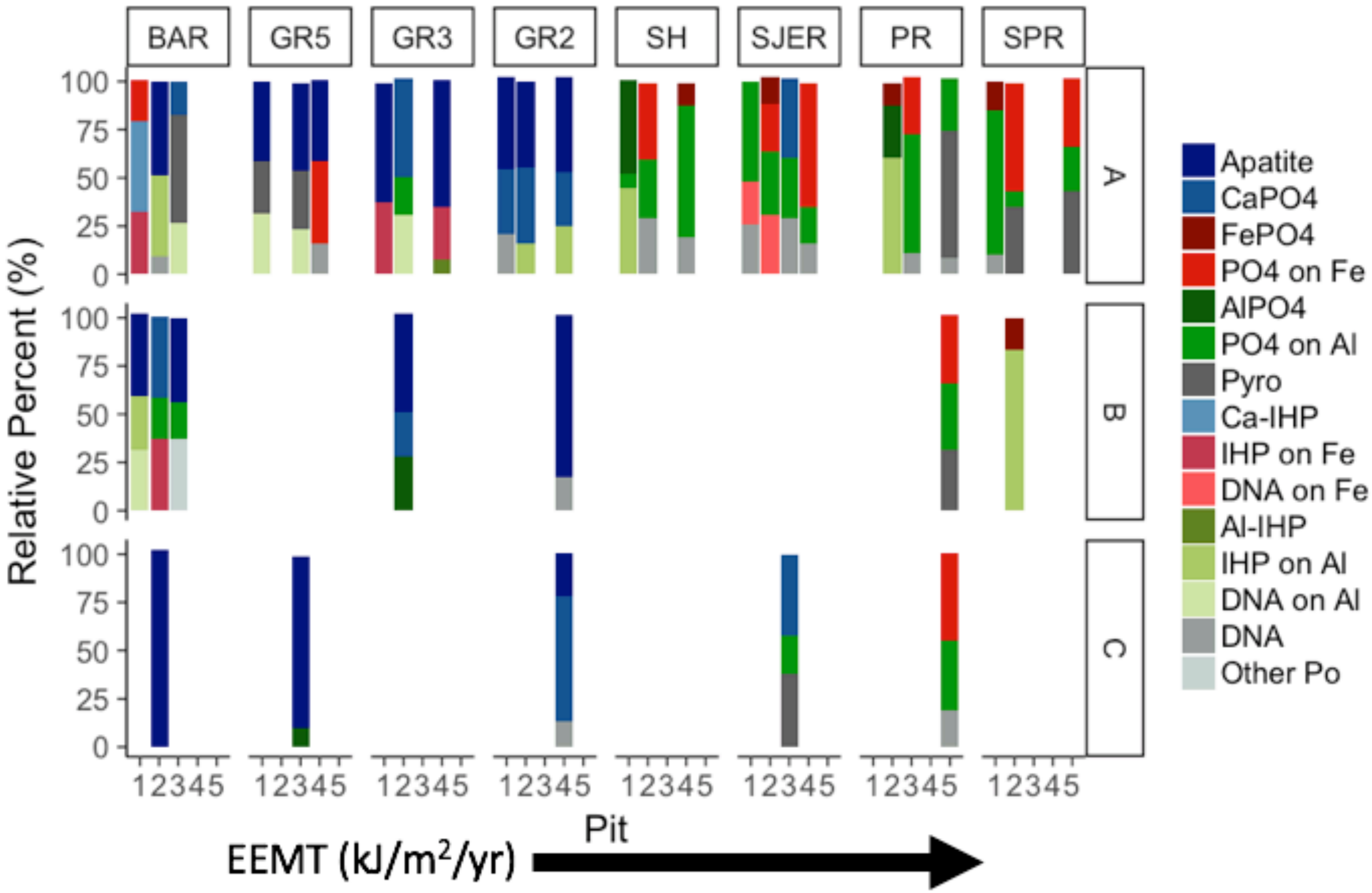
Shifts with soil weathering

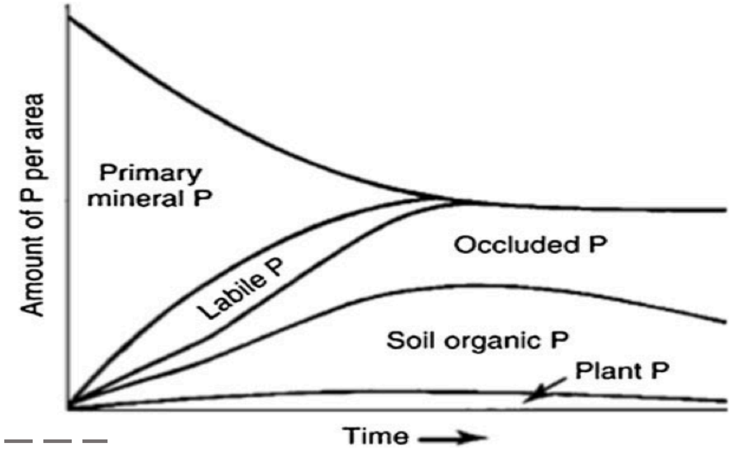
- Shift from Ca to Fe and Al associated P



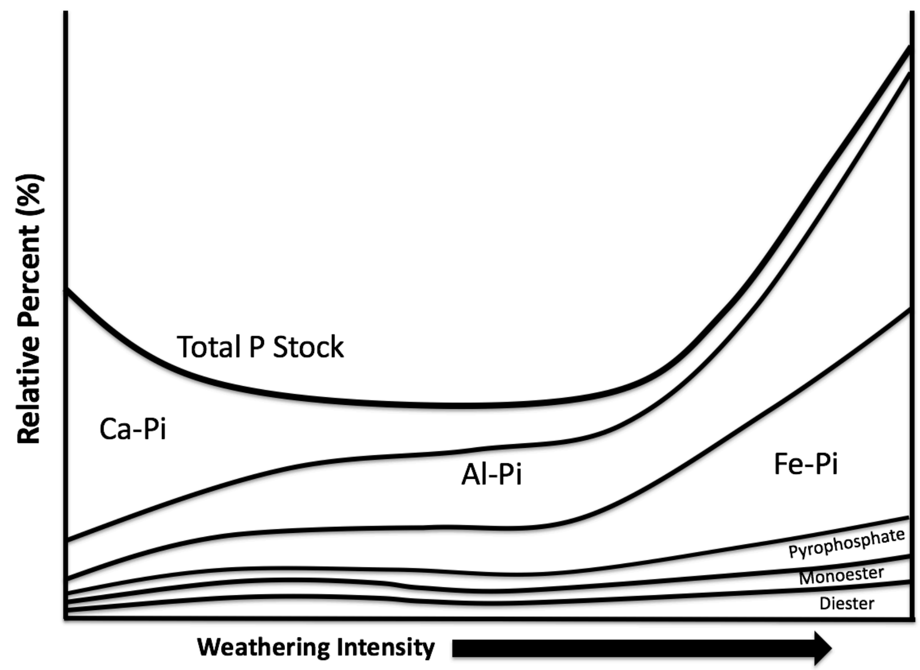
Barnes et al. (In Prep)

New conceptual model for soil P dynamics

- Traditional model (Walker & Syers 1976)
  - P biogeochemistry is related to pedogenesis



- P stock does not follow W&S
  - Deeper profiles in more weathered soil = greater stock
- P speciation follows W&S
  - Shift from Ca-P to Al/Fe- P with relatively small changes in climate
  - Little impact on Po in these moderately weathered soils



Barnes et al. (In Prep)

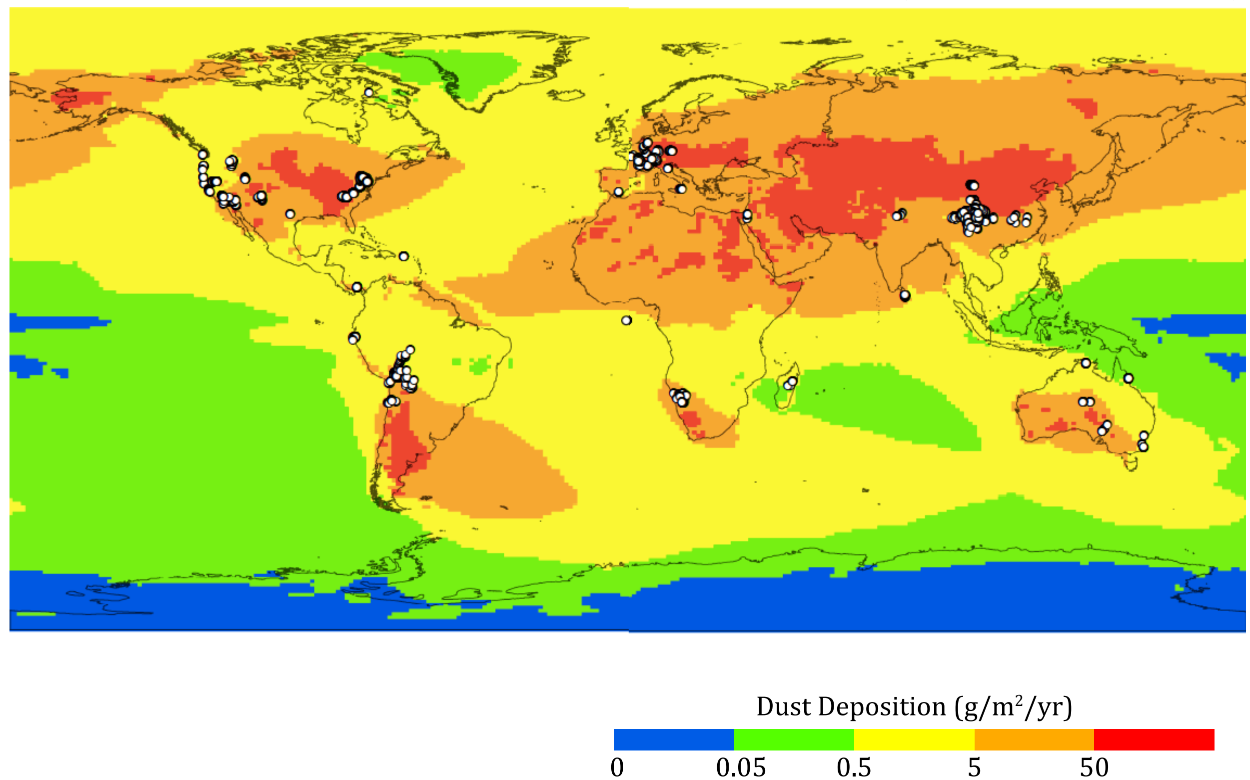
Wind erosion → Dust/Atmospheric particulate matter

- … towards inferring fate of nutrients in dust and implications for biogeochemical cycling of essential elements in the terrestrial ecosystem

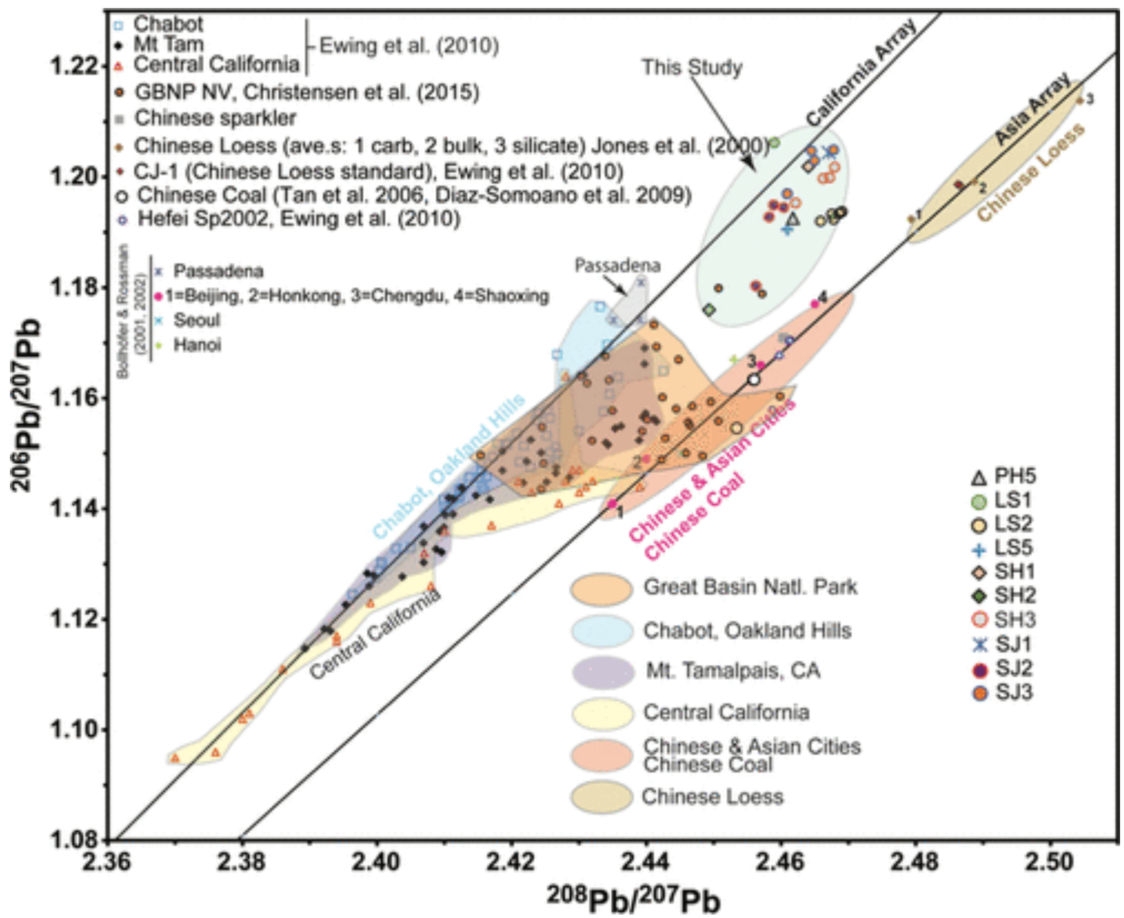
- Dust can outpace bedrock nutrient supply over the short term in soils where P concentration in bedrock is low and/or erosion and weathering rates are slow (Aciego et al. 2017)

- Plants utilize PM derived P (Arvin et al. 2017)

Model of dust deposition since Last Glacial Maximum (Albani et al., 2014)



Source of dust to W. US soils



Seasonal difference in CO

- 52% - 59% Asian source: CO (wet - winter, spring)
- 0 - 37% of Asian source: CO (dry - fall)

Elevational difference in CA

- 12 - 38% of Asian source: CA high (dry - fall)
- 14 – 22% Asian source: CA low (dry - fall)

O'Day et al. 2020 ES&T

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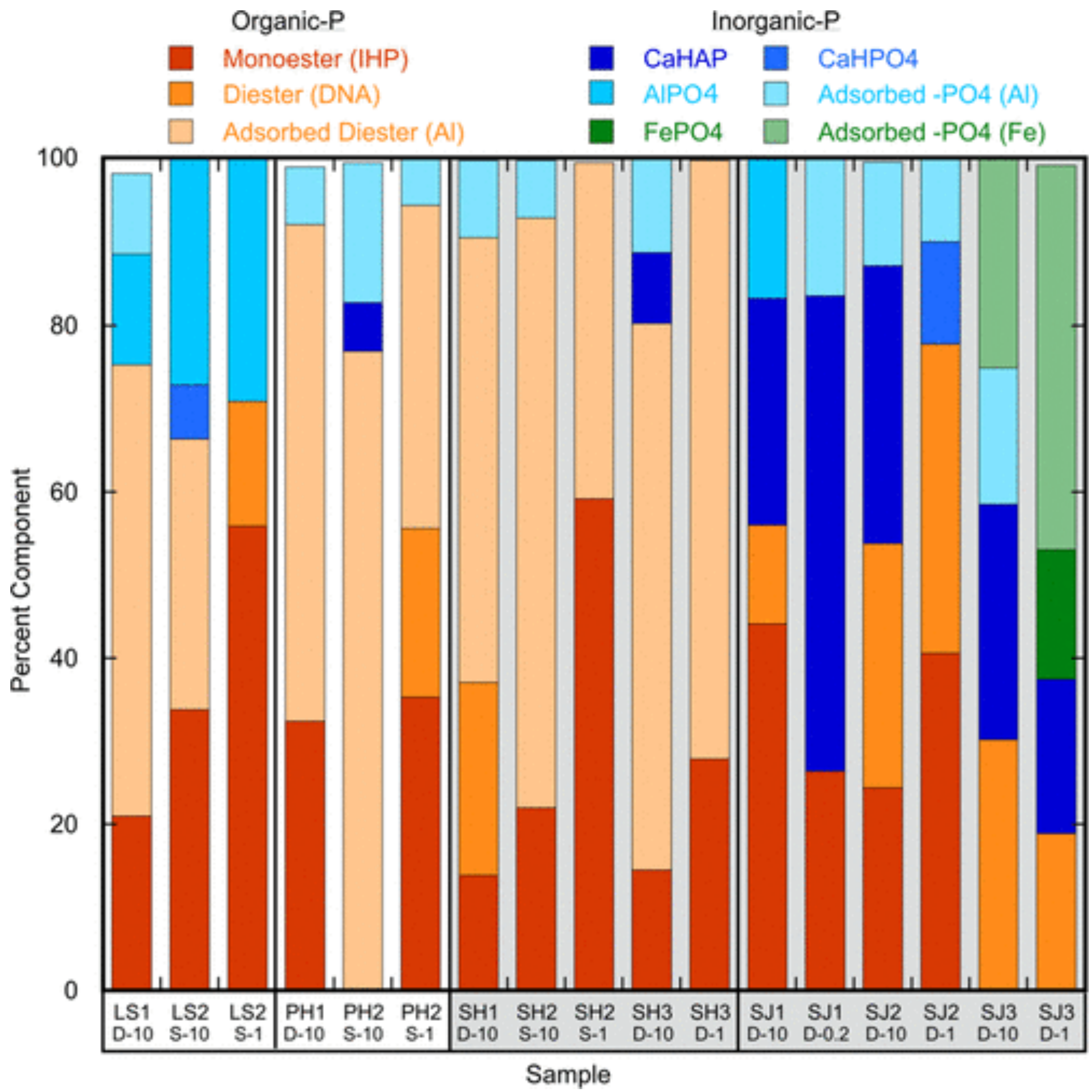
K-edge XANES: composition of bulk PM samples

- Organic P species dominant in dust collected from high-elevations in both the Sierra and Rockies



O'Day et al. 2020 ES&T

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Summary

XANES along with traditional soil science and geochemistry methods:

- Acurate representation of P extracted with sequential fractionations
- Determine how P speciation evolves during soil weathering
- Dust inputs are significant sources of plant-available nutrients, esp. in temperate forests
- Dust sources change seasonally (CO) and based on elevation (CA),
- Organic P species dominate PM samples collected from both California and Colorado high elevation systems
- Inorganic P species were prominent in the low elevation (California) site with calcium hydroxyapatite being the most dominant species (Ca abundance suggesting higher contribution of drier areas)

Acknowledgements

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